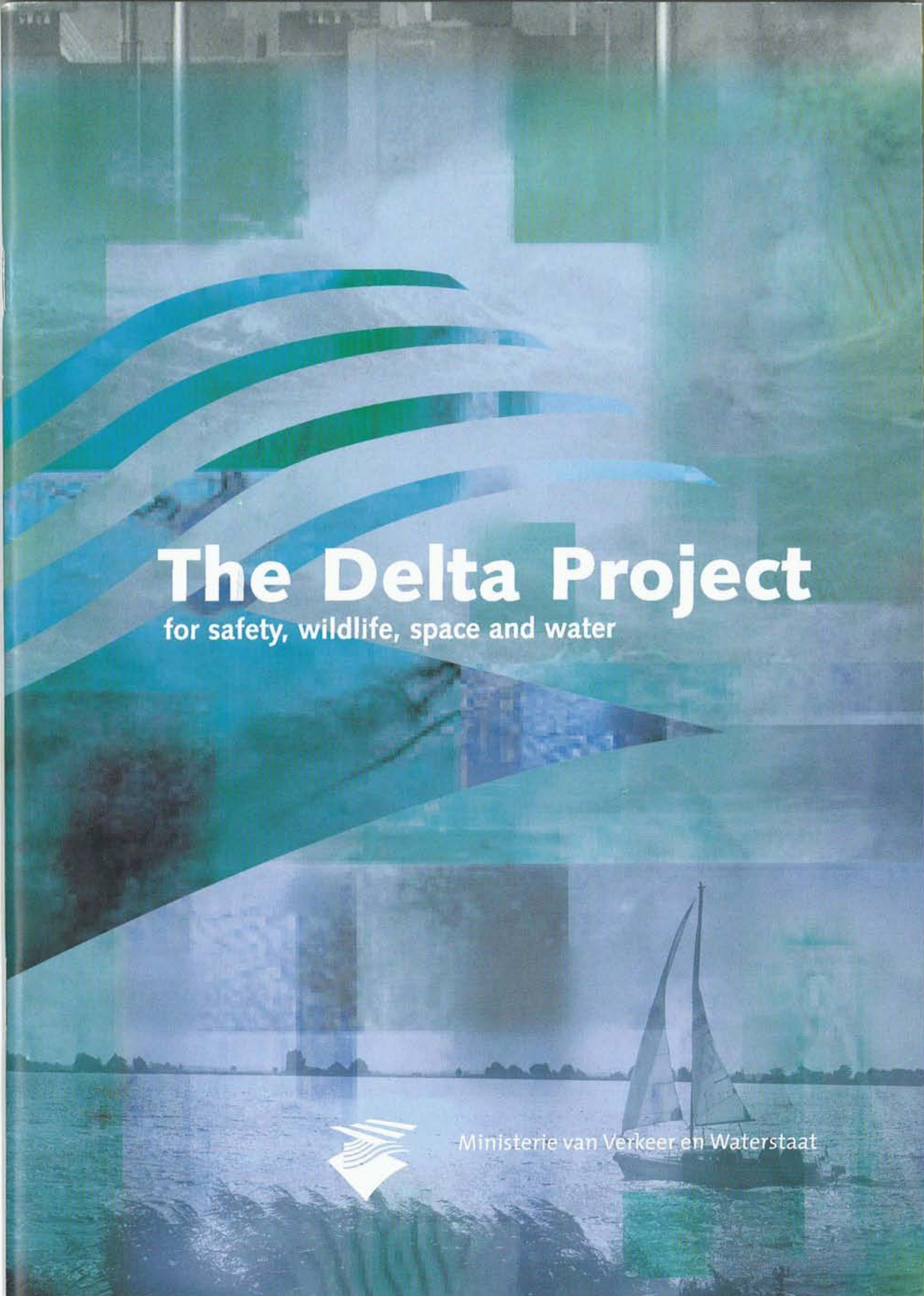
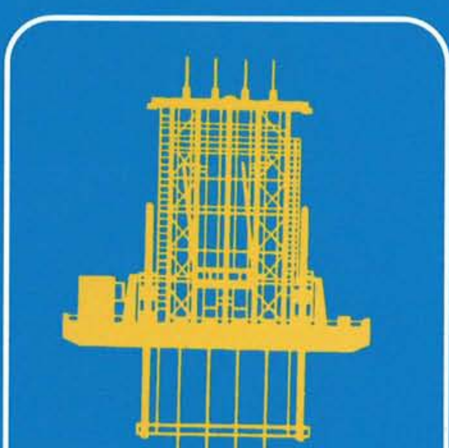


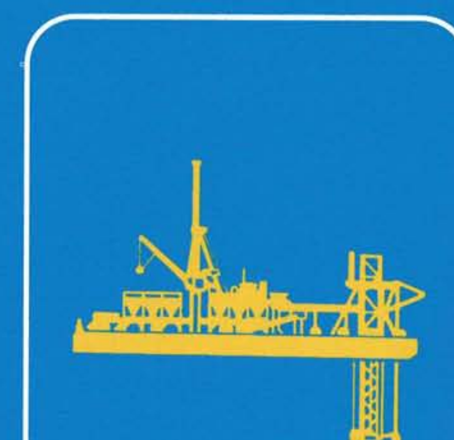
The Delta Project

for safety, wildlife, space and water

Ministerie van Verkeer en Waterstaat


Maeslantkering (1997)
Stormvloedkering
Hollandse IJssel (1958)
Voorne
Putten
Spui
Hoekse Waard
Haringvlietdam (1971)
Noordzee
Brouwersdam (1971)
Goeree
Overflakkee
Dordtse kil
Hollands Diep
Volkerakdam (1969)
Schouwen Duiveland
Grevelingendam (1965)
Philipsdam (1987)
Oosterscheldedam (1986)
Veersegatdam (1961)
Oosterschelde
Noord-Beveland
Tholen
Veerse meer
Zandkreekdam (1960)
Walcheren
Zuid-Beveland
Oesterdam (1986)
Markiezaatskade (1983)
Bathse Spui-Kanaal (1987)
Westerschelde
Zeeuwsch-Vlaanderen





The Delta Project

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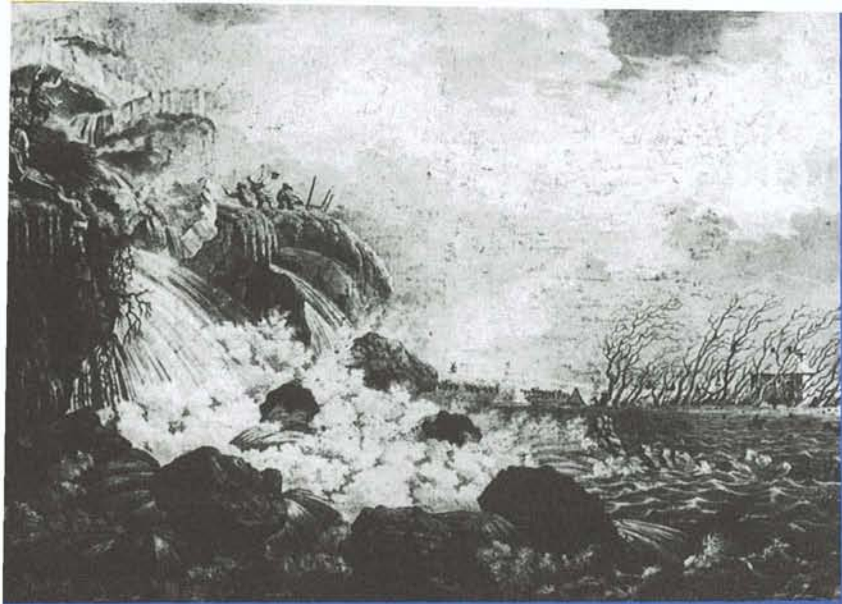
Contents



The dyke bursts at Bommel, 1809

1 The low country

This is the story of the Delta Project, one of the most revolutionary feats of hydraulic engineering ever carried out. It tells of challenges, solutions painstakingly reached and successes. It starts in 1953, reaches a triumphant climax in 1986, and ends in 1997. The Delta Project may be complete, but we will always have to protect our country against the sea.

Much of the Netherlands is below sea level. When the last ice age ended ten thousand years ago, sea level rose, forming the North Sea. The future Netherlands was uninhabitable marshland that developed into a peat bog over many centuries.

The battle with the sea started the day the first migrants settled in the Netherlands. They built their homes on the high embankments near the shore, and provided for themselves by hunting, fishing and farming. They built mounds on which they took refuge at high water.

The Romans carried out the first hydraulic engineering works. They built the first dam - not in the delta, but near Kleve in the Rhine valley. And they dug the first canals, like the Vliet near Voorburg, which links the Rhine and the Schie.

It was not until approximately the tenth century that the inhabitants started to build flood defences against the sea. The first dykes to appear along the coast were simple, low walls, made using spades and baskets. They collapsed whenever the sea launched a serious attack.

The monasteries were among the first to build dykes, which created excess water that had to be drained off. To start with, sluices were built so that water could be released from the polders at ebb tide. The windmill, invented six hundred years ago, made it possible to drain many more polders.

Floods throughout the ages

The primitive dykes of the early Middle Ages provided very poor protection against the sea. Each century had its floods. There were 111 serious or very serious floods in the West Netherlands between 1000 and 1953. Many were named after the saint's days on which they occurred. They included the St Agatha flood (1288), the St Elizabeth flood (1421, the St Felix flood (1530) and the All Saints' flood (1570).

These floods claimed many lives, as well as large areas of land, shaping the contours of the country. The Saint Elizabeth flood, on the same scale as the 1953 disaster, led to many deaths, the disappearance of the Grote Waard, and the emergence of the Biesbosch and the Hollands Diep. The All Saints' flood engulfed half of North Holland, took 5000 lives, and claimed large tracts of land in Zeeuwsch Flanders, Zuid Beveland and Schouwen-Duiveland.

In the nineteenth century, new materials like concrete, new building techniques like pitching, and the invention of the steam engine made it possible to build better and stronger dykes. But they did not defeat the sea. There were floods well into the 20th century - in 1906, and again in 1916. But the worst flood in living memory occurred on the night of 31 January 1953.

A northwester had raged for many hours, producing a surge four to five metres higher than AOD (Amsterdam Ordnance Datum, mean sea level as defined for Amsterdam). In the middle of the night, while most people slept, the sea poured over the dykes, destroying them completely in 67 places, and breaching them in four hundred others. The sea engulfed 200,000 hectares of fertile land, and many towns and villages in the southwest Netherlands. 1835 people and over 200,000 head of cattle drowned, some 72,000 people had to be evacuated, and more than 47,000 homes, factories and offices were damaged.

This time, the land claimed by the sea was not abandoned. Reconstruction work began immediately, with help from around the country and abroad. The dykes were sealed and polders drained. Contractors used methods they had tested while damming the Brielse Maas in 1950. For instance, they used large concrete structures known as caissons to block off channels.

Floods near Hedikhuizen

2 The Delta Act

A disaster of the scale that occurred in 1953 had to be prevented in the future. That was something everyone agreed on. The specially appointed Delta Committee came up with a plan in the same year. They recommended strengthening the flood defences and cutting the coastline by 700 kilometres. The shorter the coastline, the easier it would be to protect it.

The plan was not new. Long before the 1953 disaster, the government had conducted studies into ways of defending the delta area in the southwest Netherlands from onslaughts by the sea. And Dutch hydraulic engineers already had some experience reducing coastlines. In 1932, they constructed the Barrier Dam to cut the Zuyderzee off from the North Sea, creating the IJsselmeer. In one fell swoop, the Dutch coastline was shortened by 360 kilometres, and the danger of flooding was considerably reduced.

The Delta Committee proposed closing off all the inlets in the delta area, and raising all flood defences to delta level, five metres above AOD at Hook of Holland. This would reduce the risk of flooding to 1:4,000 a year in the delta area and the north, and 1:10,000 a year in the Randstad. The New Waterway and the Western Scheldt would remain open to shipping, given the economic interests of the ports of Rotterdam and Antwerp, but the dykes on these waterways would also be raised to delta level.

The Delta Act, based on the plans put forward by the Committee, was finally approved by Parliament in 1957. Besides providing protection against the sea, the Delta Project would improve water management in many parts of the country, reduce salination, produce freshwater reservoirs and create new recreational areas, while the new dams would greatly improve access to the southwest Netherlands.

Parliament debates the Delta Act, 1957. Centre: J. Algera, Minister of Transport, Public Works and Water Management

Fishers from Zeeland protest against closure of the Eastern Scheldt, early 1970s

The cableway used to construct the Brouwersdam in the Grevelingen, ca. 1970

The delta

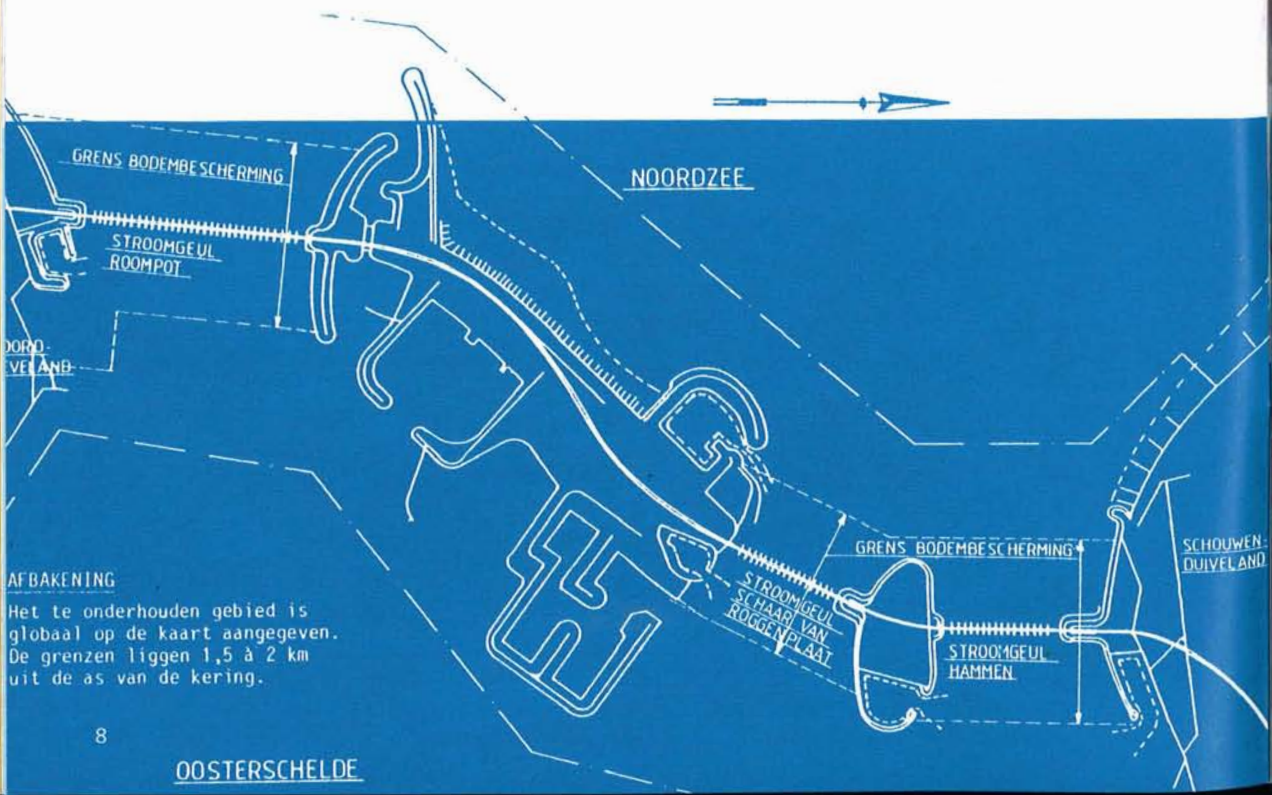
The ancient Greeks called the area round the mouth of the Nile the "delta", after the fourth letter of their alphabet, which is shaped like a triangle. In later years, this name was given to all river estuaries with several distributaries. The Rhine, the Maas and the Scheldt form the biggest delta in northwest Europe. Other famous deltas include the Ganges, the Mississippi, the Rhône and the Yangtse. Deltas are vulnerable to flooding, but their location, their fertile soil and their varied fish stocks have always drawn people to them. They are attractive places to live, and because they provide excellent opportunities for farming, fisheries, trade and industry they are of great economic importance. This is why people throughout the ages have settled in delta areas, despite the danger of flooding.




3 An engineering challenge

As originally planned, the Delta Project was to include dams closing off four inlets: the Veerse Gat, the Eastern Scheldt, the Brouwershavense Gat and the Haringvliet. This would reduce the length of the sea dykes from more than 700 kilometres to 25. Dams were also to be built further inland (in the Volkerak, for instance) to help keep the water under control.

Some special structures were also to be built to serve specific functions. A surge barrier in the Hollandsche IJssel, for example, would keep the low-lying, densely populated province of South Holland dry. Sluices in the Haringvliet dam would drain off excess water from the Rhine and the Maas into the North Sea. Locks in some other dams would allow ships through.

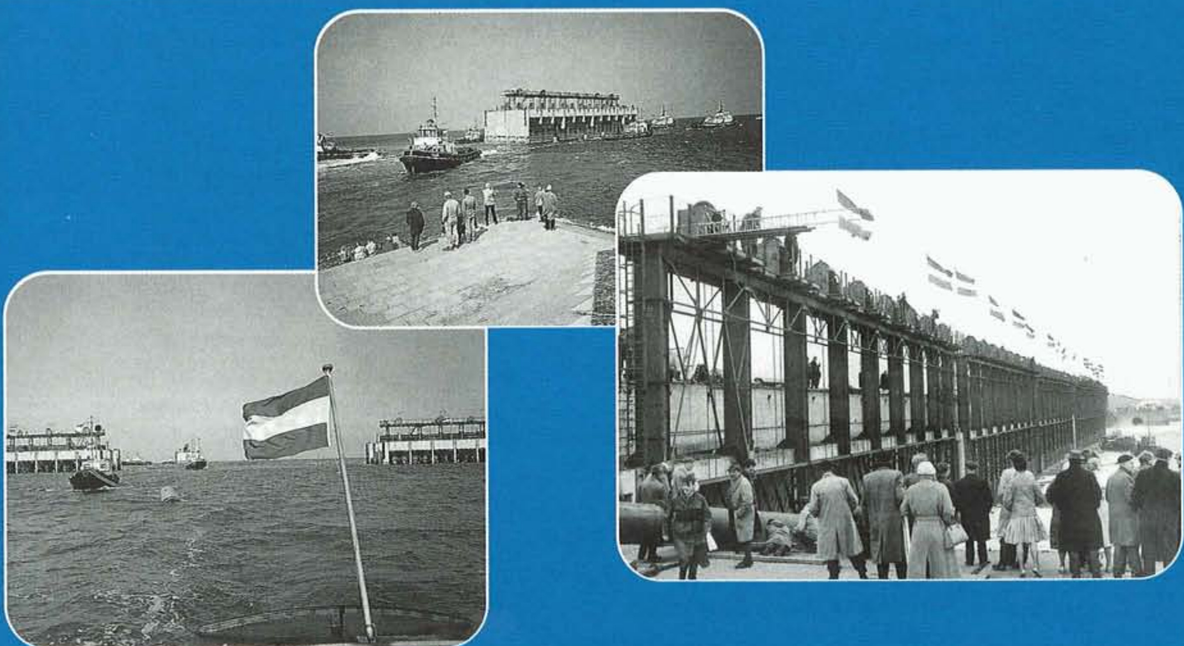


From minor to major

The Delta Project presented Dutch hydraulic engineers with an enormous challenge. No other nation in the world had ever closed off tidal inlets of this size and depth before, and the know-how and technologies needed to do so did not as yet exist. The tidal range in the Delta was approximately three metres, the sea flowed in and out of the inlets twice a day, and the current was so powerful that it shifted vast quantities of sand. What is more, weather conditions in the estuaries were often poor, and North Sea storms produced strong surges.

One thing was clear: new technologies would have to be developed fast. The engineers consciously opted to work from minor to major, starting with the relatively easy constructions and working towards the more complex ones. They could learn as they went along, developing and trying out innovative new technologies.

Prefabrication was among these innovations, and it was soon to be widely applied. New, specialist equipment was developed. 1961 saw the introduction of sluice caissons, and a cableway with gondolas was devised to carry out the work on the wider inlets. The huge concrete caissons were improved and in the 1970s man-made fibres came into use for sea and river bed protection and in dyke construction. New laboratory techniques allowed increasingly sophisticated hydrodynamic research, computers gained ground, and measuring techniques and weather forecasts became increasingly accurate. A new age had dawned for hydraulic engineering, and it looked as though the Delta Project would be completed within twenty years.



Caissons were often used in constructing the Delta dams

The first stage of the Delta Project completed: the Hollandsche IJssel storm surge barrier, 1958

4 Implementing the Delta Project

Hollandsche IJssel storm surge barrier (1958)

Construction of the Hollandsche IJssel storm surge barrier marked the start of the Delta Project. The Hollandsche IJssel runs into the New Waterway and the Maas forming an open passageway to the sea. The storm surge barrier, constructed to the east of Rotterdam, was completed in 1958 to protect the lowest-lying part of the Netherlands - at 6.5 metres below AOD - from flooding. The barrier is eighty metres long and comprises four piers that tower 44 metres above AOD and support two huge gates. In normal conditions, the gates are suspended high above the water, forming no obstacle to shipping. If the water rises to dangerously high levels, the gates can be lowered, damming the river. Ships can then pass through the lock.

Zandkreekdam (1960)

Shortly after the Hollandsche IJssel storm surge barrier was completed, the first sea inlet in Zeeland was closed off by dams. The Three Island Project, as it was known, was launched in 1953 with the aim of constructing two dams to connect the islands of Walcheren and North and South Beveland. In 1959, construction began on the smaller of the two, across the Zandkreek between North and South Beveland. The Zandkreekdam, which is 830 metres long and has a lock, was closed off with caissons in 1960.

Veerse Gatdam (1961)

A different approach had to be adopted to the Veerse Gat dam between Walcheren and North Beveland. The Veerse Gat is broader than the Zandkreek and at every tide more than 70 million cubic metres of water pass through it. Sluice caissons were used here instead of conventional caissons. The foundations of the dam were constructed on the shallows of an existing sandbank. A stone sill spanning the entire 320-metre-wide inlet was then built to support the sluice caissons, each of which was as big as a seven-storey block of flats. The caissons were left open as they were put in place to allow the water to pass through. They were closed off at slack water between low and high tide, when the sea is relatively calm. The dam was finished off in 1961. The first inlet in the Delta was now completely closed and the salt water turned brackish. Zeeland also had a new lake, the Veerse Meer, now a popular leisure area.

A sea anemone in the Eastern Scheldt

The siphon in the Grevelingendam

The Zandkreek lock between the Veerse Meer and the Eastern Scheldt

Fishing near the sluice in the Brouwersdam

Grevelingendam (1965)

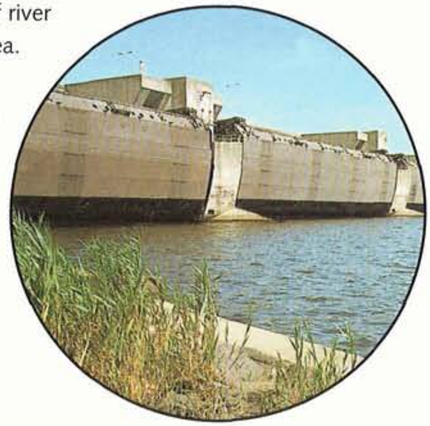
Work on the Grevelingendam between Schouwen-Duiveland and Goeree-Overflakkee started in 1958. At six kilometres, this dam is longer than both the Zandkreekdam and the Veerse Gatdam. New technologies and materials were needed to build it. Part of the dam was constructed by raising the Oude Tonge sandbank, leaving two channels open. Caissions similar to those used for the Zandkreekdam were put in place to close off the narrower of these two channels. But to close off the wider channel, the engineers came up with a new technique: gondolas on a cableway that dropped huge blocks of cement into the water. The Grevelingendam was completed in 1965.

Volkerakdam (1969)

The Volkerakdam separates the Hollands Diep and the Haringvliet from the waters of the southern Delta. Launched in 1957, the project comprised three elements meeting at the Hellegatsplein junction in the centre. Two dams were constructed, one to Goeree-Overvlakkee over the Hellegats sandbank and one to North Brabant, across the Volkerak, and a road bridge was built across the Haringvliet to the Hoekse Waard. The dam in the Hellegat was constructed completely of sand. Twelve sluice caissons were used to close off the Volkerak in 1969. Since the Volkerakdam traverses the main shipping route between Rotterdam and Antwerp, it has three huge locks and a separate lock for pleasure craft.

Haringvlietdam (1971)

Construction of the 4.5 kilometre Haringvlietdam between Goeree and Voorne took fourteen years. This dam not only protects the area behind it from flooding at high water, but also discharges excess water from the Rhine and Maas into the North Sea. That is why work on it started with the construction of seventeen drainage sluices and a lock. The sluices have steel gates which can be opened and closed to regulate the quantities of river water passing through Rotterdam's New Waterway to the North Sea. Because of its role in water management, the sluice complex is known as the Netherlands' safety valve. Once the sluices had been built, the channels on either side had to be closed off using the cableway that had been designed for the construction of the Grevelingendam. The road over the dam was opened in 1971. The construction of the Haringvlietdam closed off the second inlet from the sea.



The discharge sluices in the Haringvlietdam

The Volkerakdam near Willemstad and its locks

The Brouwersdam, between the Grevelingenmeer and the North Sea

Opposition to the closure of the Eastern Scheldt grew in Zeeland in the 1970s

Brouwersdam (1971)

The closure of the 6.5-kilometre-wide and 30-metre-deep inlet between Goeree and Schouwen was a dress rehearsal for the final tour de force of the Delta Project: construction of the Eastern Scheldt dam. Sand dams were constructed on two banks in the Brouwerhavense Gat, and the northern channel was closed off using sluice caissons. Another cableway was used for the work on the southern channel. The dam was completed in 1971, creating the Grevelingenmeer.

Changing ideas on environmental conservation in later years did away with plans to turn the Grevelingenmeer into a freshwater lake. In 1981, a sluice was built in the dam, allowing water from the North Sea to enter. This proved to be a big success: the water in the Grevelingenmeer is as salty as North Sea water, but because there is no current it is clear.

Eastern Scheldt dam (1986)

The original plan was to build a dam to close off the Eastern Scheldt. It was the most ambitious part of the Delta project. The dam would cover a distance of nine kilometres between Schouwen and North Beveland, in an inlet with an average tidal range of three metres, and a maximum depth of forty metres. Preparatory work started in 1967 with the construction of three work islands: Roggenplaat, Neeltje Jans and Noordland. A dam was built to connect Neeltje Jans and Noordland. Steel piers were constructed in the three remaining channels for the cableway from which the concrete blocks that would close off the inlet would be dropped. The dam - and with it the Delta Project - was to have been completed in 1978.

By 1973 five kilometres of dam had been built in the Eastern Scheldt. But the work was never finished. In the 1970s, growing environmental awareness led to appreciation of the unique environmental value of the Eastern Scheldt's tidal waters. Under pressure from scientists, the fishing industry and the environmental movement, parliament decided that further studies were needed.

The barrier in the Eastern Scheldt only closes when water levels are high

The prawn has survived thanks to an open Eastern Scheldt

5 'Keep the Eastern Scheldt open!'

The Eastern Scheldt was and is a unique natural habitat. The clean seawater provides a rich source of food for wildlife of all kinds. Fish use the inlet as a breeding ground, and oysters and mussels are farmed there. The inlet's mud flats, salt marshes and sandbanks form a habitat for many species of bird. If the Eastern Scheldt had been dammed, the seawater flora and fauna would have disappeared. Sea fishing and mussel and oyster farming would no longer have been possible.

The public debate was fierce, particularly in Zeeland, where the 1953 disaster was still fresh in people's memories. Opponents of the dam ultimately received support in political circles and in 1974 a compromise was proposed in the form of a dam built up of elements that would allow seawater through. In 1975 the government decided on a storm surge barrier, with sliding gates. This solution would protect against flooding, while conserving the ecosystem.

Revolutionary

Nowhere in the world had such a barrier been designed or built before. The technology needed to construct it had yet to be invented, and the experience gained building the other dams in the Delta was insufficient. In the short time at their disposal, the engineers came up with a solution that was as simple as it was revolutionary. They proposed building an enormous storm surge barrier in the Eastern Scheldt that would remain open when conditions were normal, and would be closed when water levels were high.

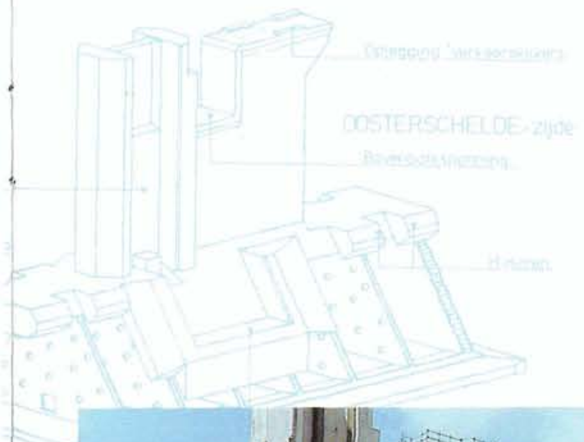
The idea was to place concrete piers in a very firm stone foundation, and to insert sixty-two sliding gates between them. Tides would largely be unaffected and the water in the inlet would remain saline, but safety would be guaranteed. Parliament approved this plan in 1979.

6 Construction of the Eastern Scheldt storm surge barrier

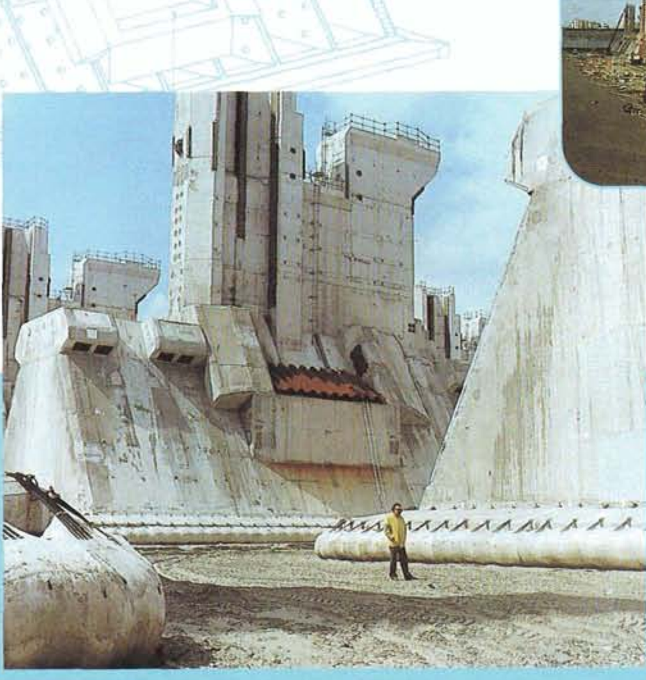
The Eastern Scheldt storm surge barrier was such an exceptional project that a new approach had to be taken to every part of its construction. A consortium of Dutch contractors was formed and cutting-edge methods and materials were used.

Step by step

First, the foundation for the piers was built up step by step. It had to be very solid, because the bed of the Eastern Scheldt is constantly shifting. Polypropylene mats, with concrete blocks attached to them, were used to protect the bed on which the barrier would stand. The sludge was dredged, and *replaced by sand. Then the Mytilus*, a ship specially built to compact the seabed in the Eastern Scheldt, inserted four enormous steel rods into the bed. By vibrating the rods, grains of sand up to a depth of fifteen metres could be packed closely together. The sea bed became solid ground.



Constructing the piers for the Eastern Scheldt barrier



At slack water, the Cardium rolled out the mats that protect the bed of the Eastern Scheldt

A carpet in the sea

To prevent sand being flushed away when the barrier was closed, and to make sure the piers were standing on a level surface, an even firmer foundation was needed. Mats were used for this purpose, made up of polypropylene filled with sand and grit.

A separate factory was built to manufacture these mats, from which they were rolled around huge, floating cylinders. The mats were then unrolled on to the seabed. The rough waters in the inlet made this extremely painstaking work. The mats had to be rolled out quickly in exactly the right place. The work could only be done at slack water, when the tide turned.

The final result was a foundation that was more level than many football pitches. Right across the mouth of the Eastern Scheldt, a smooth carpet, two hundred metres wide, awaited the construction of the piers.

A backbone of piers

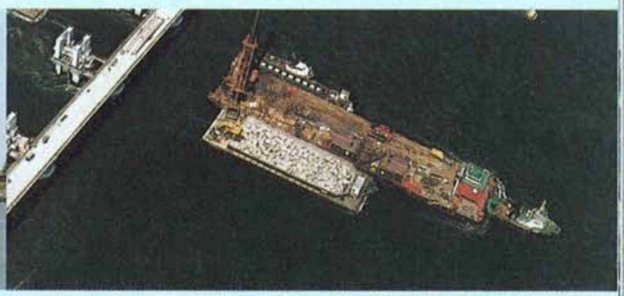
65 colossal piers form the backbone of the barrier. They were built at three enormous construction docks. Each is a hollow concrete form, thirty to forty metres high, and weighing 18,000 tons. The exact height of each pier depended on its place in the channel. A special unit was set up to produce the concrete, and it took nearly a year and a half to produce each pier. Production was staggered, with work on a new pier starting every two weeks. When all the piers in a construction dock were finished, the dock was submerged, and the surrounding dyke was opened so that they could be transported to one of the three channels in the Eastern Scheldt.

Putting the piers in place

Two vessels were positioned in the mouth of the Eastern Scheldt, and they worked together to sink the piers in the right place. The Ostrea lifted the huge piers out of the construction dock, and transported them to the channel, placing them onto the mats within a margin of error of just a few centimetres.

The operation had to take place at slack water, and it took a year to sink all 65 piers. Once they were in place, the space between the foot of the pier and the mats was sealed off with grout, a mixture of sand, cement and water. The lower sections of the hollow piers were then filled with sand to make them more stable.

The Ostrea was built specially to bring the piers into position



The Trias lays huge blocks of stone on the bed to protect it against powerful currents

Five million tons of stone

For even greater stability and protection from the powerful currents that would arise if one of the gates refused to open, the piers were embedded in sills made up of blocks of stone weighing up to ten thousand kilograms. Since dropping these heavy stones into position could damage the piers, the Trias was designed specially to lay the top layer. This vessel was equipped with a long, extendable arm that could place the heaviest stones accurately. Five million tons of stone were needed, and since it was not available in the Netherlands it was shipped over a four-year period from Germany, Finland, Sweden and Belgium.

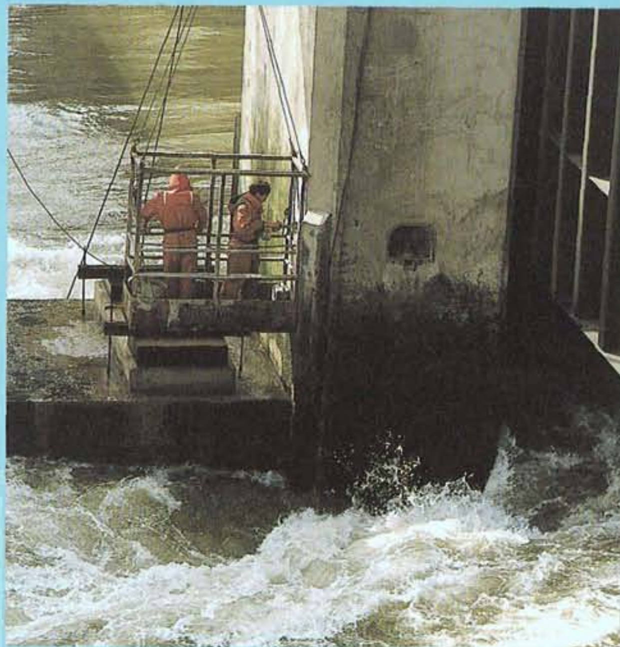
The finishing touches

The main part of the storm surge barrier was now complete. At the final stage, the service ducts, pier capping units, gates, sill beams and upper beams had to be put in place. The hollow service ducts, which would later be covered by a road, were laid on top of the piers. The ducts contain the operating and control equipment for the gates. The steel gates, varying in height from six to twelve metres, were suspended between the piers. They are made of steel cylinders and thin sheets of steel on the Eastern Scheldt side. Each is equipped with two hydraulic cylinders to control its movements. The biggest gate weighs 480 tons and hangs in the deepest channel, the Roompot. It takes 82 minutes to close. The Roompot lock was constructed in the southern section of the work island to allow shipping through.

Queen Beatrix officially opened the Eastern Scheldt storm surge barrier on 4 October 1986. It cost more than 2.7 billion euros, and gave Zeeland the protection it had so urgently sought. It marked the completion of the Delta Project's final major feat of hydraulic engineering. The Eastern Scheldt could remain open to the North Sea, and its tidal ecosystem was conserved.

The Mytilus compacts the bed with vibrating steel rods

The floating crane Taklift 4 puts the gates in place



The Eastern Scheldt storm surge barrier is operated from the Topshuis

When do the gates close?

The Eastern Scheldt storm surge barrier is operated from the Topshuis on Neeltje Jans. The gates have to be closed at extremely high water - twice a year on average. For the rest of the year, they remain open. Only when water levels of more than three metres above AOD are forecast are they closed - well in advance. If something goes wrong either in operating the gates or sounding the alert, an emergency system closes the gates automatically. An early warning system has also been developed that takes account of long-term forecasts.

The situation in the Eastern Scheldt basin is factored into any decision to open or close the gates. Operating the barrier affects the environment, fisheries and the water management system, as well as the safety of the dykes that surround the Eastern Scheldt.

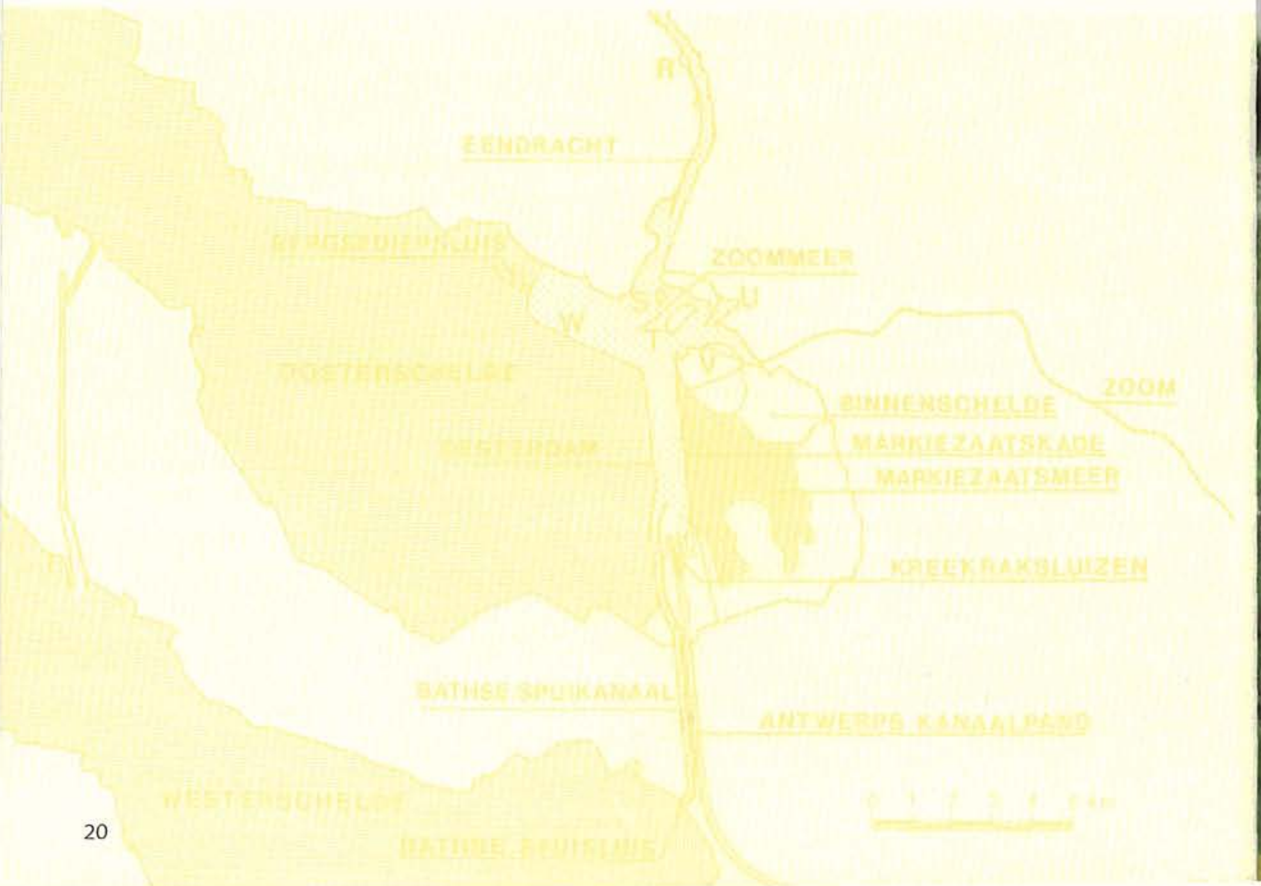
7 A smaller Eastern Scheldt

The construction of the storm surge barrier made the channel in the Eastern Scheldt much narrower. The natural consequence would have been that far less water flowed in and out of the inlet at high and low tide. Since the tidal range would then have become much smaller, many mud flats and sandbanks would have disappeared. To prevent this happening, the Eastern Scheldt basin had to be compartmentalised, or reduced in size. Two compartmentation dams, the Oesterdam and the Philipsdam, both with locks for shipping, were therefore constructed in the east and northeast. These dams also keep seawater and freshwater separate, and keep the Scheldt-Rhine link tide-free.

Oesterdam (1986)

The Oesterdam was constructed between Tholen and Zuid-Beveland in 1986. Eleven kilometres in length, it is the longest of the Delta dams. By partly closing the gates of the Eastern Scheldt barrier to reduce the tidal current, the dam could be constructed entirely of sand.

A few years before work on the Oesterdam started, the Markiezaatskade, a dyke, was constructed along the Verdronken Land at Bergen op Zoom so that currents would not pose a problem to shipping during the construction work. The Markiezaatsmeer, a freshwater lake, formed behind it.



Construction of the seawater/freshwater separation system in the Krammer locks

Philipsdam (1987)

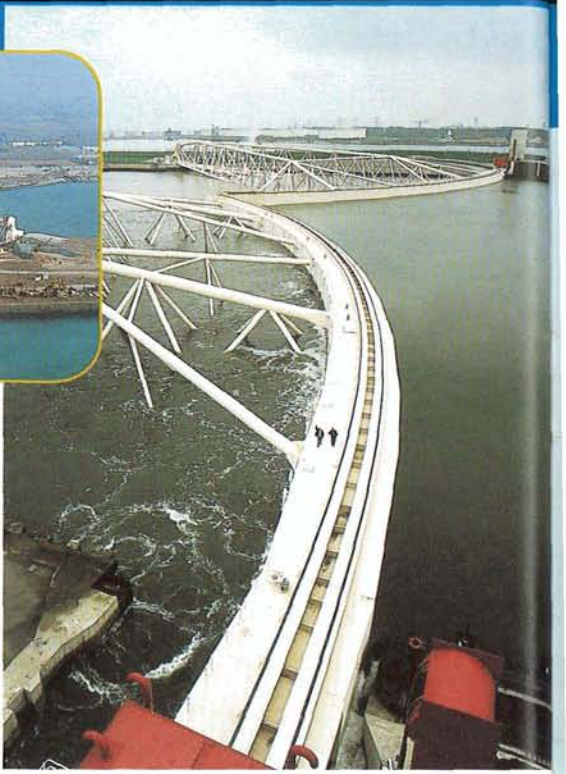
The Eastern Scheldt barrier was also partly closed to allow construction of the Philipsdam between Sint Philipsland and the Grevelingendam in 1987. Like the Oesterdam, the Philipsdam was constructed of sand. The Krammer locks in the dam are equipped with a system to prevent too much sea water from the Eastern Scheldt entering the freshwater Krammer/Volkerak, and vice versa, when ships are locked through.

The Bath Discharge Canal (1987)

The engineering works in the Delta area brought about changes to the water management system. Water is now drained from the land into the Volkerak and Zoommeer peripheral lakes behind the compartmentation dams. The lakes thus serve as collector basins. But water also has to be discharged from rivers and polders if necessary. The Volkerak sluices had already been built to allow water from the Hollands Diep to be discharged into the Volkerak and Zoommeer. However, river water was rarely allowed into the peripheral lakes, since the toxins it contained could severely pollute their beds. The solution was the Bath discharge canal, dug through South Beveland at its narrowest point. At low water, the canal can discharge 8.5 million cubic metres of river and polder water per day into the Western Scheldt through the sluice in its outlet.

The Bath discharge canal under construction

The Maeslant barrier in the New Waterway near Rotterdam was completed in 1997



A trial closure

8 The Maeslant barrier

When Queen Beatrix opened the Eastern Scheldt storm surge barrier in 1986, she declared victory in the battle with the sea. This was not entirely the case. In 1997, the Delta Project would finally be completed with the opening of the Maeslant storm surge barrier in the New Waterway.

The original Delta Project involved sealing off as many sea inlets as possible in the southwest Netherlands. But the Western Scheldt and the New Waterway had to stay open, to allow shipping to reach the ports of Rotterdam and Antwerp. Nonetheless, the land on either side of both waterways had to be protected from flooding, and a major dyke reinforcement operation was launched. The dykes on the banks of the Western Scheldt, the New Waterway and the Maas were raised.

In the 1970s, however, city-dwellers came out against reinforcing the dykes, since it often involved the demolition of historic buildings. What is more, later estimates showed that the dykes would have to be raised even higher, at great cost. The solution was to build a storm surge barrier in the New Waterway.

In 1987, the Ministry of Transport, Public Works and Water Management organised a competition for the best design. Unlike the Eastern Scheldt barrier, the barrier on the New Waterway could not pose an obstacle of any kind to shipping. And it would have to eliminate the need to raise the dykes in and around Rotterdam. The barrier could only be closed when water levels were extremely high, no more than once or twice every ten years. The winning design had two curved gates, kept in docks on the banks most of the time, that can be pivoted out into the canal and sunk to form a barrier against flood tides. Building started in 1991.

The New Waterway barrier

The Maeslant barrier was completed in 1997. The New Waterway at the Hook of Holland is now graced with an imposing, white construction that can be seen for miles around. It looks weightless, but its powerful arms are capable of closing off the 350-metre-wide waterway if Rotterdam is threatened with water levels of over three metres above AOD. It is the only storm surge barrier in the world with such huge moving parts. The gates are as tall as the Eiffel Tower.

The Maeslant barrier comprises two gates each 210 metres tall, which normally lie in docks on either shore. If a storm surge threatens, these docks are submerged, so that the hollow doors float. Within half an hour they can be transported to the middle of the New Waterway. Once they meet, the valves in the walls open, so that they fill with water. The gates then sink and stop above the concrete sill on the bed. The powerful current under the gates flushes sludge from the sill, and within an hour the gates have landed on the clean sill, protecting the area behind them from flooding.

The barrier has a number of highly innovative components. The gates, with their 28 hollow compartments, may be the most striking. Much smaller and less visible are the special ball-and-socket joints which allow the doors to move in any direction. Ten metres in diameter, and weighing 680 tons, these joints are similar to the human shoulder joint, and move in much the same way. They are unique in the world.

A computer system decides whether or not to close the Maeslant barrier, calculating probable water levels in Rotterdam and Dordrecht on the basis of water and weather forecasts.

Putting the ball and socket joints in place

The barrier gate is floated out of its dock

The Europoort barrier

The Maeslant barrier alone could not protect the entire New Waterway and Maas region from flooding. Two more flood defences were needed - the Europoort barrier and the Hartel storm surge barrier. The Europoort barrier is a dyke that runs from Rozenburg to the southern end of the Maeslant barrier, and to the southeast, where it joins the Hartel barrier. This entire project, including the Maeslant barrier, the Europoort barrier and accompanying dyke reinforcements, cost more than 635 million euros. That is approximately 18.5 million euros less than the costs of the old dyke reinforcement programme, which would have taken many years to complete.

In the next fifty years, the Maeslant storm surge barrier will probably have to be closed once every five years, due to sea level rise. The port of Rotterdam is temporarily closed to shipping when the barrier is tested once a year.

The Hartel barrier is the last element in the Europoort barrier

9 Water management new style

The Delta Project is complete, the battle against the seas has been won. Now we can rest on our laurels. Or can we? Changing attitudes to the environment, the consequences of the Delta Project, climate change (in particular heavy rainfall), sea level rise and ongoing soil sinkage mean there will always be work to do. When, in 1995, the Maas and Rhine rose to dangerously high levels, a foreign newspaper remarked that the Dutch had sealed off the front door, only to find they were threatened from the back. However, it is water from the skies that now poses the greatest threat. Climate change has led to more rainfall, often reaching 100mm a day. Flooded polders, like those in Delfland in 1998 and 2000, are the result.

In a country by the sea, made up largely of rivers, lakes, canals and polders, water is an overriding concern. New ideas on water management are now being applied along the North Sea coast, the river banks and in the IJsselmeer region. In the Delta region too, thinking on water has changed radically since the launch of the Delta Project. In the aftermath of the 1953 floods, the Netherlands' sole concern was to protect its land against the sea. Now a much broader approach is called for, embracing the entire region and all its inhabitants, from people, who want to keep their feet dry, to the smallest sea urchin living on the walls of the Eastern Scheldt dyke.

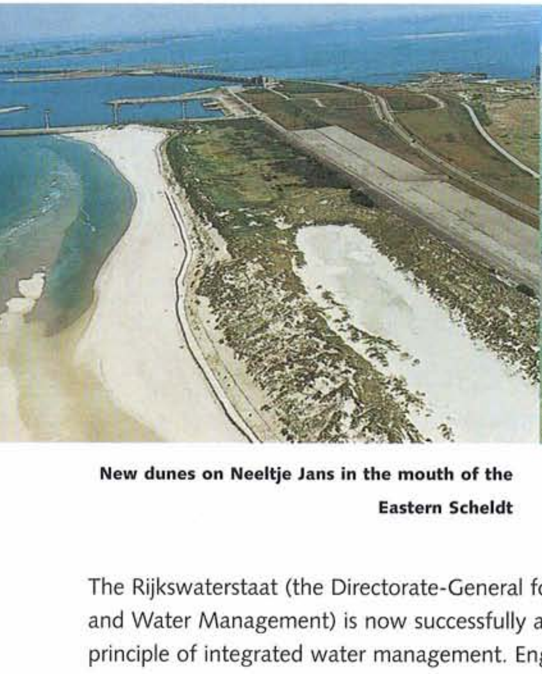
Opposition to the plans to close off the Eastern Scheldt was the first manifestation of a growing environmental awareness. Since the late eighties, the government has actively responded to this new trend in its master plan for water management new style. Known as integrated water management, this approach takes account of the interests of the entire delta region - from water quality, environment, nature, fisheries and the leisure industry to fresh water supplies, farming, shipping and industry. But protection against flooding continues to be the main concern.

Changing water systems

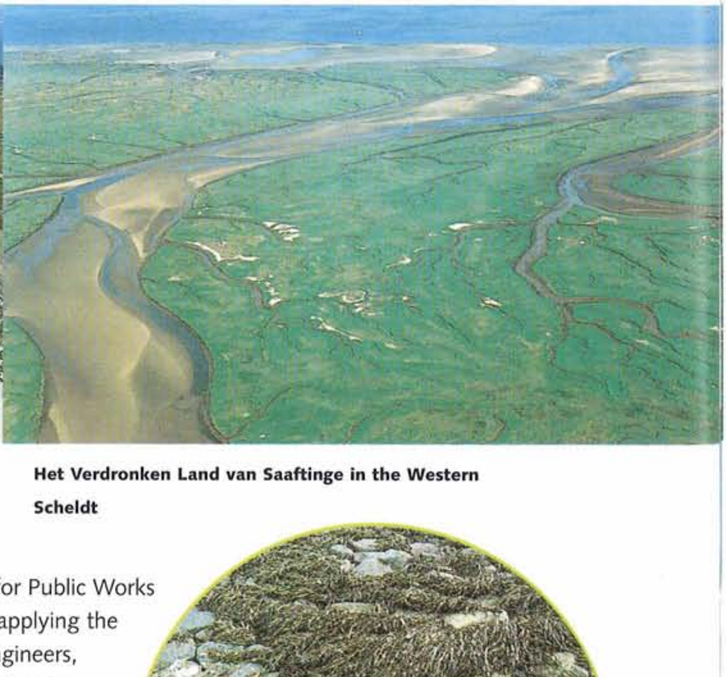
The Delta Project has had a number of unexpected effects on the environment. Closure of the sea inlets provided security, but also led to colossal changes to the water systems in the Delta region.

The tides, whose influence had been felt far inland, disappeared. There was no longer a gradual transition from sea to fresh water, and flora and fauna suffered. Channels and creeks silted up. Mud flats and sandbanks disappeared under water, and the shoreline eroded due to the water constantly washing up against it. Because there was no longer an open passage to the sea, polluted river sludge had the chance to settle.

Many of these changes are irreversible. The fresh water of the Brielse Meer will never be saline again. But the aim is not to return to the old situation but to mitigate the effects of human intervention, and to conserve, restore and develop ecosystems wherever possible. The water systems in the Haringvliet, the Hollands Diep and the Biesbosch can be restored more or less completely.



New dunes on Neeltje Jans in the mouth of the Eastern Scheldt



Het Verdronken Land van Saaftinge in the Western Scheldt

The Rijkswaterstaat (the Directorate-General for Public Works and Water Management) is now successfully applying the principle of integrated water management. Engineers, ecologists and morphologists each have a role to play. Unsightly flood defences have given way to environmentally friendly shores. Sand is now allowed to drift freely in some places in the dunes, producing areas of natural beauty. New breeding islands have been created to attract different species of bird, and fish stocks are increasing thanks to the creation of nurseries.

Plants growing on a dyke

Nature development: weighing the pros and cons

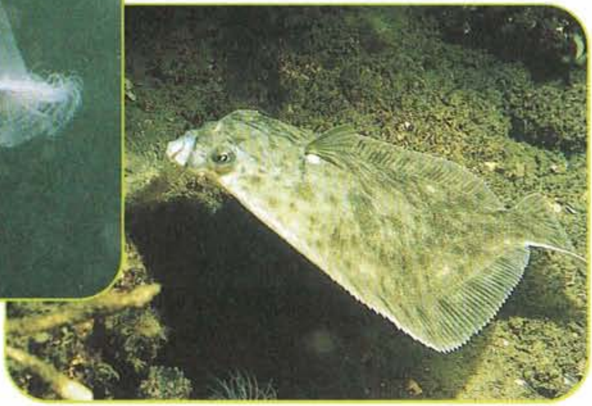
Since 1985, the new approach has inspired many nature development projects in the Delta. They vary from environmentally-friendly flood defences - protecting vulnerable shorelines with dams - to the creation of dunes and sandbanks for birds. The dunes have developed into areas of natural beauty along the Dutch coast, where hawthorn and spindle trees grow. And Neeltje Jans, the former work island, once the location of concrete factories and construction docks, is now a haven of rest, with bird sanctuaries, gullies and dunes.

Water management new style calls for continual assessment of the situation, to decide whether and where to intervene, develop new nature areas, or allow nature to take its course.

The Haringvlietdam ajar

When the Haringvlietdam was built in 1970, the Haringvliet was sealed off from the sea, the water turned fresh, and tides more or less disappeared. Fauna and flora in and around this stretch of water changed radically. Migrating fish like shad, eel, smelt and stickleback, which used to swim in and out of the Haringvliet inlet and used it as a breeding ground, suddenly found their way blocked by a dam. Typical estuary species that needed sea or brackish water could not survive in the fresh water. Their place was taken by freshwater species. But the dam is a problem for them too. When the sluices are opened, the water carries them along into the sea, and the sudden change from fresh to sea water kills them.

Whether or not to open the Haringvlietdam sluices, effectively turning the dam into a storm surge barrier, was a topic of much debate in recent years.



Underwater wildlife in the Eastern Scheldt: left a jellyfish, right a flounder

Taming the tides

On the basis of in-depth studies, an alternative was decided on. The waters of the Haringvliet will again become tidal, albeit with a smaller range. The process will be carried out gradually. For 95 percent of the time, the sluices will be a third of the way open, giving the Haringvliet's natural habitats the chance to revive. The tides will become noticeable, with a range varying from 65 centimetres to a metre.

The waters will accommodate fewer freshwater species, but species needing brackish water are likely to return. There will be more bird species, and migrating fish will find their way back to the major rivers. Mud flats and sand banks in the Haringvliet and the creeks and gullies in the Biesbosch will revive, and in time the area will develop into a true estuary, with the Biesbosch becoming the largest freshwater tidal region in Europe. This alternative solution will lead to silting, but the Rijkswaterstaat believes that compensatory measures and good sluice management will solve this problem.

The sluices cannot be opened from one day to the next. Compensatory measures will take time and money. The lion's share of the budget will be taken up with measures to safeguard the drinking water supply, and for farming, fisheries and shipping. For this reason, changes to sluice management will be introduced in stages, with the sluices open only slightly to start with.

Slowly but surely, the compensatory measures will be carried out, and the problem of silting solved. It will take ten to fifteen years before gentle tides return to the Haringvliet.

The tidal range will double when the Haringvliet sluices are left ajar

10 The future of the Delta's waters

Is the Delta Project now complete? Has the final chapter in this story been written, now that the dykes have been brought to delta level, the Maeslant barrier is in place, and innovative nature development projects are nearing completion?

The low country is getting lower and sea level rose by 20 centimetres in the last century. In the future, it is likely to rise by between 10 and 90 centimetres a century, and water depletion and soil sinkage are leading to further subsidence. At some time in the future, the flood defences will have to be raised, and new measures will be needed to cope with rising levels of water in our rivers.

The Eastern Scheldt, now so safe thanks to an ingenious feat of engineering, is still tidal, so that the dykes along its shores need constant maintenance. In some places, the walls have to be reinforced.

The environment in the Eastern Scheldt calls for constant attention. The barrier has weakened the tide, and the contours of the bed are levelling out, channels are shallower and banks, mud flats and salt marshes are eroding. It is possible that in the coming years freshwater from the rivers will be allowed into the Eastern Scheldt, provided it is not polluted. This would produce more food, and give the environment the boost it needs. The Eastern Scheldt could again be an area in which freshwater and seawater meet, and a better tidal environment might well be the result.

We will have to learn from experience as we did during the Delta Project. This low-lying country has been wrestling with the water for two thousand years. Water management in a place like the Netherlands is a story without an ending.

The Eastern Scheldt storm surge barrier

Colofon

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